NASA-CR-204632

FLORIDA A&M UNIVERSITY - FLORIDA STATE UNIVERSITY

COLLEGE OF ENGINEERING

INTERIM REPORT

for the period

May 1, 1996 - December 31, 1996

on

A COOPERATIVE RESEARCH PROGRAM IN AERONAUTICAL INFORMATION SCIENCE TECHNOLOGIES

Grant No. NCC2-956

Submitted to

NASA Ames Research Center

Moffett Field, CA 94035-1000

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May 8, 1997

Grant Number NCC2-956 began as a collaboration between Florida A&M University (FAMU) and NASA Ames Research Center (ARC) with the sole purpose of conducting research on problems of current interest to ARC. This cooperative program is intended to filling the national need for increased participation of African American students in scientific and engineering research of aeronautical information science technologies.

The research tasks identified under this program are:

1. Flow physics/modeling of aeroacoustic phenomena
2. Novel instrumentation/measurement techniques for large scale wind tunnel applications
3. Information systems research for state-of-the-art advances in aeronautical technologies.

Task 1. Flight effects on the far-field noise of a supersonic jet.

The influence of forward flight on the far-field noise of an underexpanded heated jet has been studied experimentally using a 12.5 cm diameter convergent nozzle operated in the NASA Ames 12.2m x 24.4 m (40'x80') wind tunnel. The nozzle was operated at nozzle pressure ratios up to 4.5 and stagnation temperature ratios from 2.45 to 3.45. The resulting velocity (based on fully expanded condition) range is from 586m/sec to 858 m/sec. The free stream Mach number was varied from 0 to 0.32. Far-field narrow band spectra were obtained at angles (measured from the inlet axis) covering a range from 30^{o} to 155^{o}. A small amplification of the OASPL (2dB) due to forward flight is observed in the forward quadrant. The mixing noise reduction in the aft quadrant due to forward flight is much smaller than that observed in corresponding cold jets.

The detailed discussion of the results are given in a paper to be published in AIAA Journal: A. Krothapalli, P.T. Soderman, C.S. Allen, J.A. Hayes and S.M. Jaeger., "Flight Effects on the Far-Field Noise of a Heated Supersonic Jet, *AIAA Journal*, **35**, June1997.

Task 2. Off-Axis Particle Image Velocimetry for Large Scale Wind Tunnel Applications

Velocity field measurements in large scale wind tunnels, such as 40'x80' wind tunnel at Ames Research Center, require special arrangement of image acquisition apparatus such as the camera and associated optics. From our experience of conducting experiments in the 7'x10' wind tunnel, it is suggested that the image acquisition apparatus be placed outside the tunnel test section. In order to accomplish this, an Off-axis PIV has been developed as described below.

Usually in PIV measurements the measurement plane and the optical axis of the image receiving system are perpendicular to each other, because it is simpler to focus and to process the image for this configuration. But for many cases this configuration may not be applied because of various reasons, such as the image receiving system can disturb the flow field itself, it may be hazardous or difficult to align and adjust the system inside the test section. This is usually the case when the secondary flow field is being investigated as in jet flows, vortex flows and most of the 3-D flows.

For such cases off-axis PIV can be used to overcome these disadvantages. In the off-axis configuration the optical axis of the image receiving system does not have to be perpendicular to the measurement plane, so that one can put the system to a more appropriate position in the test section or even out of the test section, and can get more illumination making use of the directional light scatter characteristic of the particles.

The off-axis (non-perpendicular) configuration causes some difficulties in the alignment and focusing, and the processing phases because there is a non-uniform magnification in the field.

The focusing problem can be overcome by the Scheimpflug condition as described in the figure 1.1,

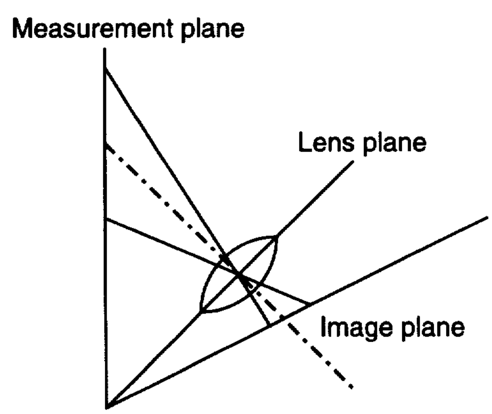


Figure 1.1 : Scheimpflug condition for focusing to whole field at an off-axis angle.

If all the object (measurement) plane, lens plane and the image plane intersect at a point as shown in the figure 1.1, then the Scheimpflug condition is met and the focus to the whole field is obtained. If this condition is applied, the clear image is captured, but since there is a perspective difference in the field now, the magnification is not uniform any more.

An other important side of the off-axis configuration is the importance of the out of plane component of the velocity field. If there is an out of plane velocity component, then it is directly captured by the receiving system and it has to be corrected by a second system at a different angle. But this becomes an advantage, because by using these two receiving systems it is possible to identify whole 3-D velocity vector field in the measurement plane. That is called stereoscopic PIV.

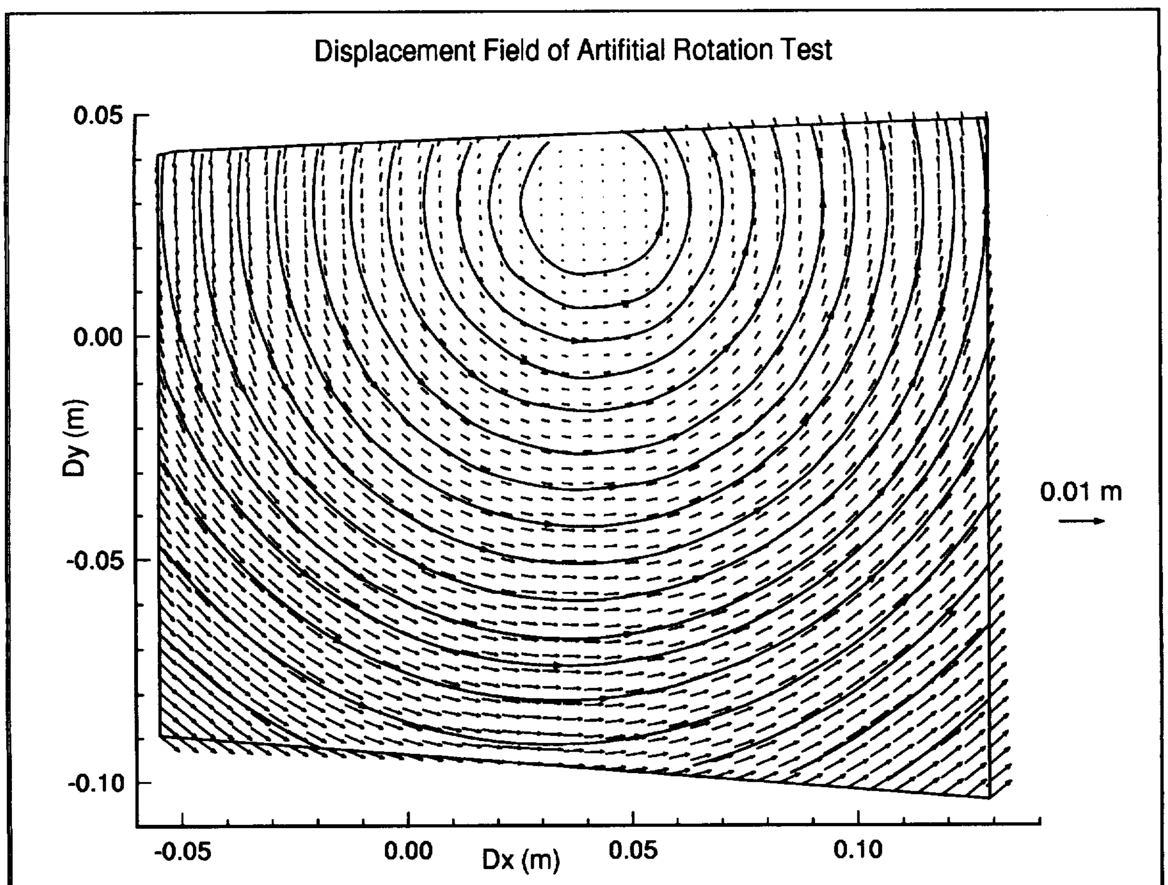


Figure 1.2 : Artificial rotation test case for an off-axis angle of about 40°.

Preliminary results has been obtained for the off-axis PIV on a simple artificial rotation test case. The lens was mounted on an especially designed 5-DOF mechanism for easy alignment and focusing purposes. As a measurement plane a plate was used, where the plate was rotated by a fixed amount. Then the processing was completed including the non-uniform magnification calculations and correction. The rotation of the plate was fully measured, as shown in the figure 1.2, from an angle of about 40°.

After being confident with the system, it was applied to a real flow case at a cross-section in rectangular pipe jet. The off-axis angle was about the same. The alignment and focusing were successfully obtained. Since the out off plane velocity component was the primary flow direction, the measured vector field was totally biased with that component as can be seen in the figure 1.3. But this test was made just to validate the ability to focus and to have data in a real flow field. After all, to put a second camera and to make the stereo PIV is just an extension of calculation.

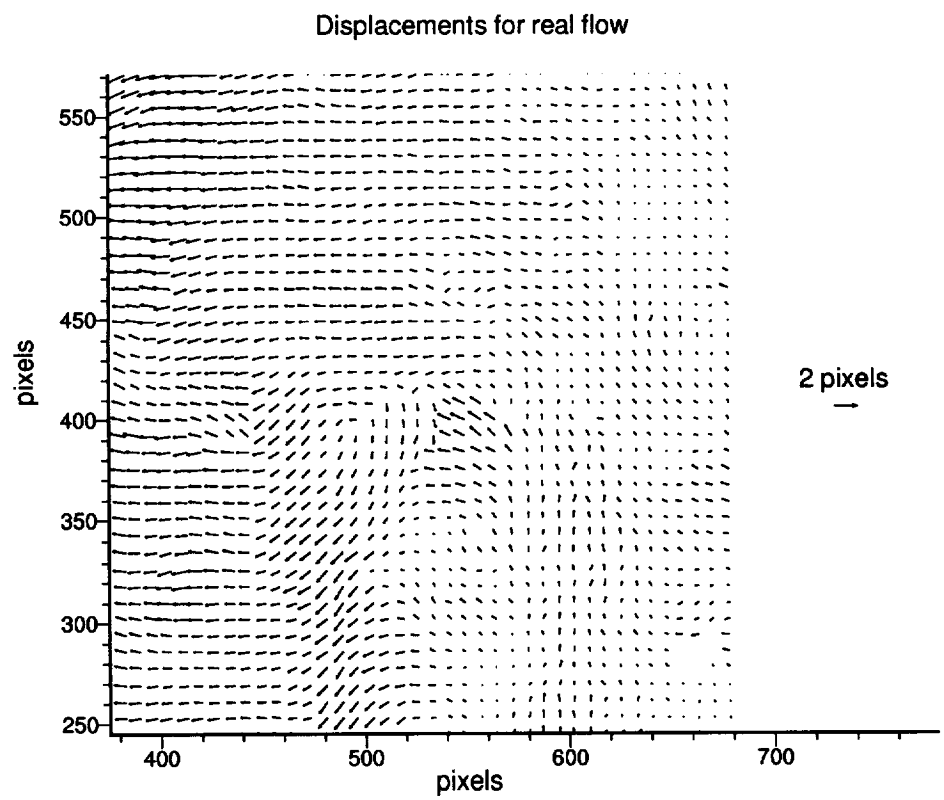
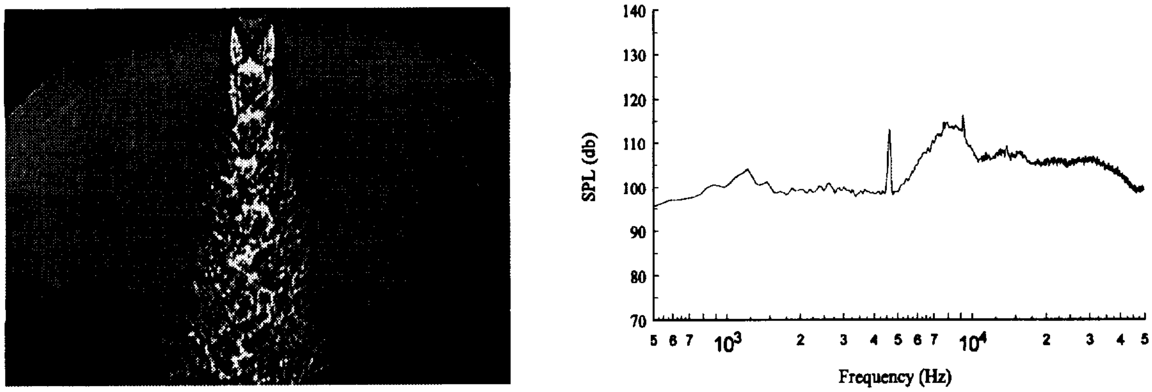


Figure 1.3 : Measured displacement field of a cross-section in a jet flow with an off-axis angle of about 40°.

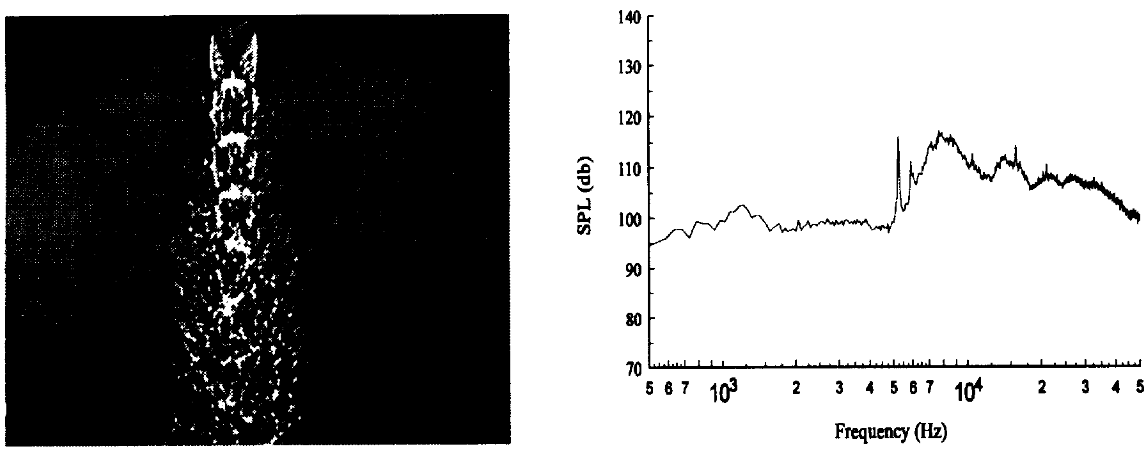
Task 3: STOVL jet flow field investigations.

The focus of this experimental investigation is to provide fundamental understanding of the role of nozzle pressure ratio and geometry of the nozzle on the entrainment characteristics of an impinging supersonic jet that is exiting from a circular plate. The jet exits from a convergent nozzle/convergent-divergent (C-D) nozzle. The nozzle exit diameter for the convergent nozzle is about 2.54 cm while the throat of the C-D nozzle is about 2.54 cm with a design Mach number of 1.64. Three circular discs were made with pressure taps to obtain the lift loss on the plate due to the jet.

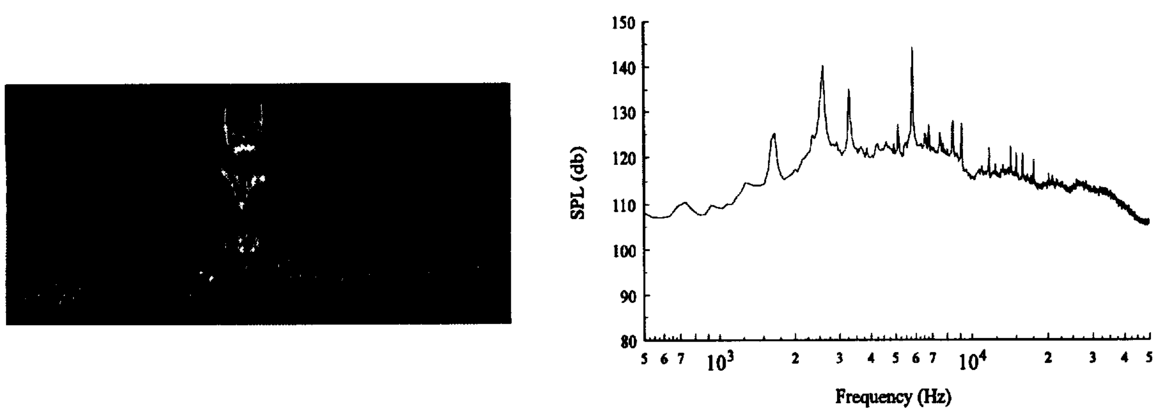
Measurements include schilieren flow visualization, near field acoustics and Particle Image Velocimetry (PIV) measurements. The experimental set up is being calibrated and some preliminary results are included in Figure 2.1 and 2.2. Both these figures show shadowgraph and corresponding near field noise spectra of an axisymmetric converging jet at three different conditions (free jet, free jet with lift plate and jet with lift plate impinging on a ground plane located at 5 diameters downstream of the jet exit). Screech tones that are commonly observed in free jets are observed in the frequency spectra of the free jet. For the case of an impinging jet, in addition to screech tones, impinging tones are observed at the lower nozzle pressure ratios (figure 2.1). However, when the NPR was increased to 4, the tones associated with impingement disappear. The presence of ground plane always increases the overall sound pressure levels. The associated effects on suck down force are being measured currently.



Free jet without lift plate

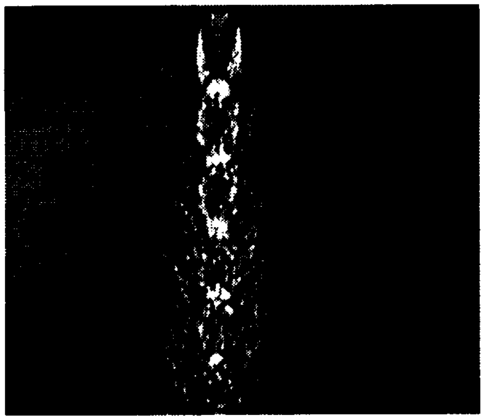


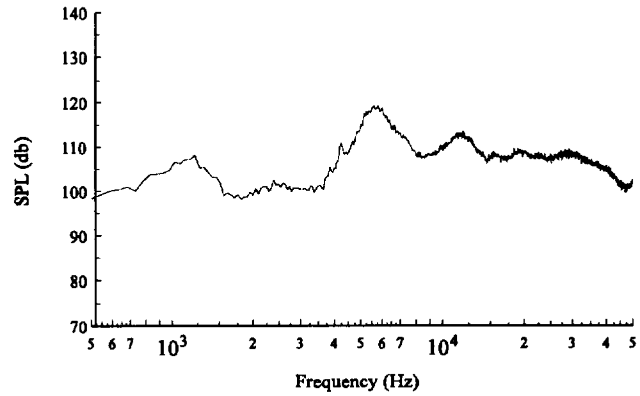
Free jet with lift plate



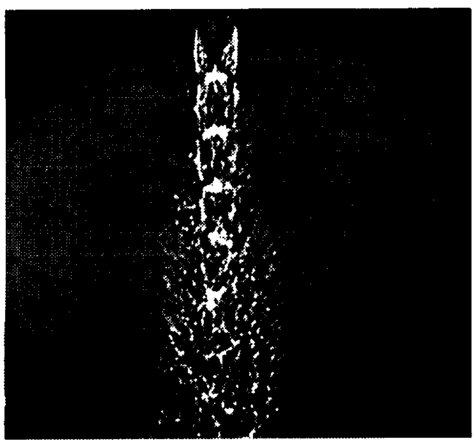
Jet with lift and ground plate (L/D = 5)

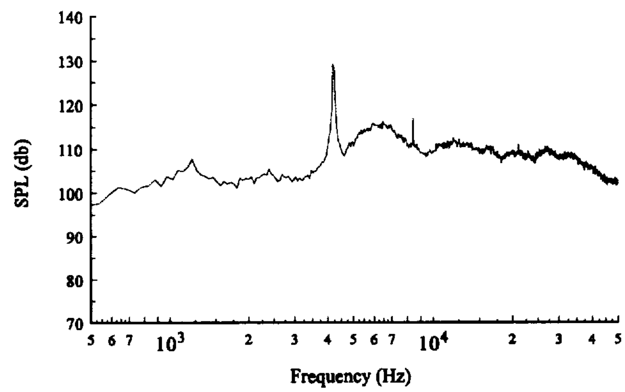
Figure 2.1 : Shadowgraph and Noise Spectra for NPR = 3



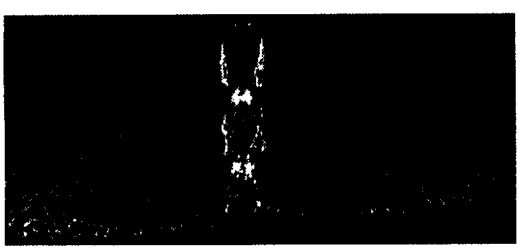


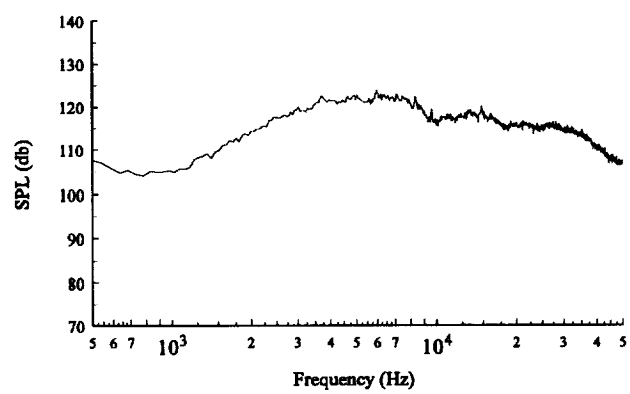
Free jet without lift plate





Free jet with lift plate





Jet with lift and ground plate (L/D = 5)

Figure 2.2 : Shadowgraph and Noise Spectra for NPR = 4